NANOMOTION

A Johnson Electric Company

HR8

Ultrasonic Motor

User Manual

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Limited Warranty

Nanomotion (hereinafter NM) warrants the product (other than software) manufactured by it to be free from defects in material and workmanship for a period of time of one year (except those parts normally considered as consumable/expendable components such as motor conditioning brushes). The warranty commences thirty (30) days from the date of shipment.

NM warrants those parts replaced under warranty for a period equal to the remaining warranty coverage of the original part.

NM's sole and exclusive obligation under this warranty provision shall be to repair, or at its sole option exchange defective products or the relevant part or component, but only if : (i) the Purchaser reports the defect to NM in writing and provides a description of the defective product and complete information about the manner of its discovery within ten (10) days of its discovery; (ii) NM has the opportunity to investigate the reported defect and determines that the defect arises from faulty material, parts or workmanship; and (iii) the Purchaser returns the affected product to a location designated by NM. These provisions constitute the exclusive remedy of the Purchaser for product defects or any other claim of liability in connection with the purchase or use of NM products.

This warranty policy applies only to NM products purchased directly from NM or from an authorized NM distributor or representative.

This warranty shall not apply to (i) products repaired or altered by anyone other than those authorized by NM; (ii) products subjected to negligence, accidents or damage by circumstances beyond NM control; (iii) product subjected to improper operation or maintenance (i.e. operation not in accordance with NM Installation Manuals and/or instructions) or for use other than the original purpose for which the product was designed to be used.

The warranty stands only when the motors are used with the NM drivers/ amplifiers.

NM shall not in any event have obligations or liabilities to the Purchaser or any other party for loss of profits, loss of use or incidental, increased cost of operation or delays in operation, special or consequential damages, whether based on contract, tort (including negligence), strict liability, or any other theory or form of action, even if NM has been advised of the possibility thereof, arising out of or in connection with the manufacture, sale, delivery, use, repair or performance of the NM products. Without limiting the generality of the preceding sentence, NM shall not be liable to the Purchaser for personal injury or property damages.

CE Compliance

The motors and drivers comply to the following directive:

Safety : IEC 61010-1:1990

EMC : 89/336/EEC as amended by 92/31/EEC and 93/68/EEC

Harmonized Standards to which conformity is declared:

EN 50081- 2:1993/EN 55011:1991

Generic Emission Standards Class A for radiated emission and Class B for conducted emission.

EN 50082- 2:1995 Generic Immunity Standard

NOTE: UHV motors are designed for convenient interface to the UHV setup. The motors are therefore supplied with three open electrical leads. Whereas standard motors comply with CE regulations and the UHV motors have the same internal design as standard motors, the UHV motors are supplied as components and CE conformity in both EMI and Safety must be implemented as part of the UHV system design.

Preface

This user Manual is designed to help the user in installing and operating the various types of Nanomotion's HR8 Piezoceramic Motors. This manual assumes that the reader has a fundamental understanding of basic servo systems, as well as motion control concepts and applicable safety procedures.

The manual describes the physical dimensions as well as the mechanical and electrical installation procedures for these motors.

Warranty

The motors are covered by warranty for a period of twelve months from the date of invoice.

The following voids the warranty:

Misuse or incorrect mounting, incorrect electrical connections, removal of motor cover or of serial number, modification of parts, and any other use that is not according to the cautions and warnings provided in this guide.

Liability for replacement will be determined after inspection of any defective item by Nanomotion or an approved agent.

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1 Definition of Terms

CAUTION: Identifies conditions or practices that could result in damage to this product or other property.

⚠ ***WARNING: Identifies conditions or practices that could result in personal injury,*** **damage to the product *or other property*.**

1.1 ⚠ WARNINGS

- Do not remove the cover of the motor or disassemble its connector. High voltage inside.
- Be sure to ground the motor to the electrical network ground (according to the following instructions) before operating the motor.

1.2 CAUTIONS

- Arrows on motor indicate direction of motion. Align accordingly.
- Do not set power-on unless motor is mounted and preloaded!
- Do not immerse the motor in any liquid or cleaning agent.
- Use only a clean cloth to wipe the motor.
- Be sure that the motor, and especially motor's 'finger tips', are not subjected to mechanical shocks.
- Be sure that the distance of the motor to the Ceramic Driving Plate enables the motor's 'finger tips' to contact the Ceramic Driving Strip, otherwise the motor might be damaged during operation.
- The mounting base and the method used for mounting should be designed for maximum mechanical rigidity and stiffness.
- Reducing the length of the supplied motor cable may damage the motor. Do not attempt to shorten the cable without prior confirmation from Nanomotion.
- Extending the motor cable will not damage the motor, however it will affect its performance.

2 Introduction

2.1 About the Motor

The HR8 motors are high precision ceramic motors. Designed and manufactured by Nanomotion, Ltd. The HR8 motors, combine unlimited stroke with high resolution and compact dimensions. Among its applications are microscopy, precision motion, robotics, etc.

The motors provide a linear response to the input voltage. The specifications described in this chapter apply only to the motor driven by AB1A driver. Minor differences may result if AB2 driver, AB4 driver or AB5 driver are used.

2.2 Vacuum Motors

Applications of the Nanomotion motors for vacuum and high-vacuum environments include wafer inspection and metrology, scanning stages and lithography. The HR8-V and HR8-U motors are constructed of materials that have been selected and designed for high vacuum compatibility.

2.3 HR8 System Parts

A complete set for a single axis will comprise of the following:

a) HR8 Motor

b) Ceramic Driving Strip for linear applications or Ceramic Driving Ring/Disk for rotary applications.

c) One of the following drivers:

- AB1A
- AB2
- AB4
- AB5

2.4 Handling

CAUTION:

Do not set power-on unless the motor is mounted and preloaded!

Do not immerse the motor in any solvent or cleaning agent.

Use only a clean cloth to wipe the motor.

Be sure that the motor, and specially motor's 'finger tips', are not subjected to mechanical shocks.

2.5 Installation and Servicing

It is recommended to follow the installation instructions in this guide, when mounting and installing the motor. The HR8 does not contain any user-serviceable parts.

3 Preparation and Installation

3.1 Preparation

For optimal motor performance, it is recommended to use the Ceramic Driving Strip provided by Nanomotion. These Ceramic Driving Strips have been specifically designed to work with Nanomotion motors.

Substituting this strip with any other material might reduce motor performance or damage the motor.

Note:

- *The instructions given in this section refer to the standard Ceramic Driving Strips provided by Nanomotion. Nanomotion does not guarantee performance attained by strips purchased from other sources.*

3.1.1 Mounting Base

Prepare the base as described further in this section – Mounting Base Dimensions. The base should be positioned perpendicular to the Ceramic Driving Strip that is bonded to the stage.

If necessary, refer to the schematic for motor dimensions.

CAUTION:

The mounting base and the method used for mounting should be designed for maximum mechanical rigidity and stiffness.

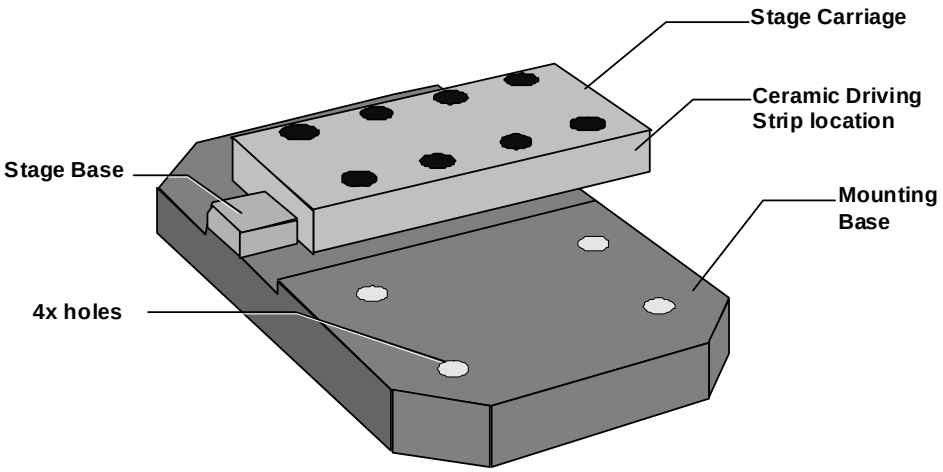

Figure 1: Motor Mounting Base

The mounting base dimensions diagram refers to the *front* surface of the Ceramic Driving Strip.

Available Ceramic Driving Strip (CS) dimensions for HR8 motor are as follows: CS-20-3-XXX, where “20” is the width, “3” is the thickness and “XXX” is the standard lengths. Available standard lengths: 50, 100, 150, 200, 250, 300, 350, 400 and 500. All dimensions are in mm.

For other dimensions please contact Nanomotion (see chapter 5 for Contact Information).

The four screws securing the motor to the mounting surface will be inserted from its underside. Protrusion of the screws *might* interfere with motion on another axis.

3.1.2 Limiting Stage Motion

The provided Ceramic Driving Strip should not exceed the stage. It must be supported by a solid even backing along all its length, in order to avoid breaking when motor is pressed against it.

The Ceramic Driving Strip should also be at least 20 mm longer than the stage travel length, otherwise the motor's 'finger tips' might be damaged. If the above requirements are not met, limit the stage travel distance using end stops.

3.2 Motor Installation

The installation procedure consists of:

- Bonding the Ceramic Driving Strip to the stage
- Mounting the motor
- Grounding the motor
- Connecting the motor to its driver

3.2.1 Bonding the Ceramic Driving Strip to the Stage

The Driving Ceramic Strip interfaces between motor's 'finger tips' and the stage, and provides the required friction.

Bond the driving plate to the stage surface interfacing with motor's 'finger tips', according to the instructions given in this section.

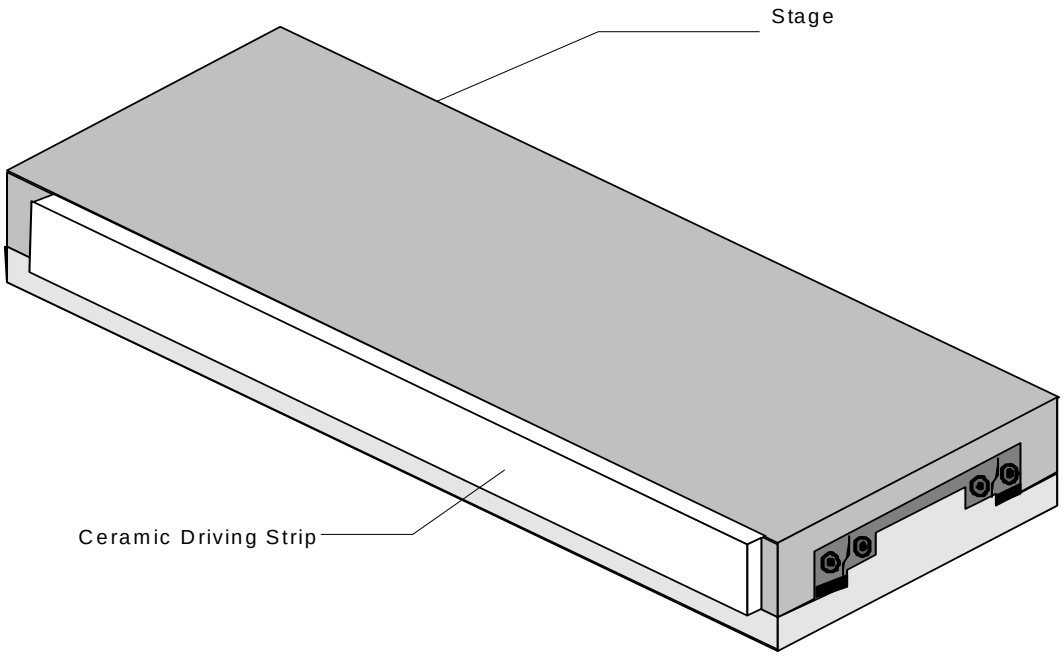

Figure 2: Bonding the Ceramic Driving Strip

1. Clean the bonding region on the stage, using a suitable agent such as Acetone or Methanol.
2. Peel off the self-adhesive backing paper on the Ceramic Driving Strip. The self adhesive tape is compatible with high-vacuum applications.
3. Referring to the figure below, place the plate in position, verifying that:
   - There is a maximum of 3.5mm between the lower edge of the Ceramic Driving Strip and the motor mounting surface.
   - There is a minimum of 21mm between the upper edge of the Ceramic Driving Strip and the motor mounting surface.

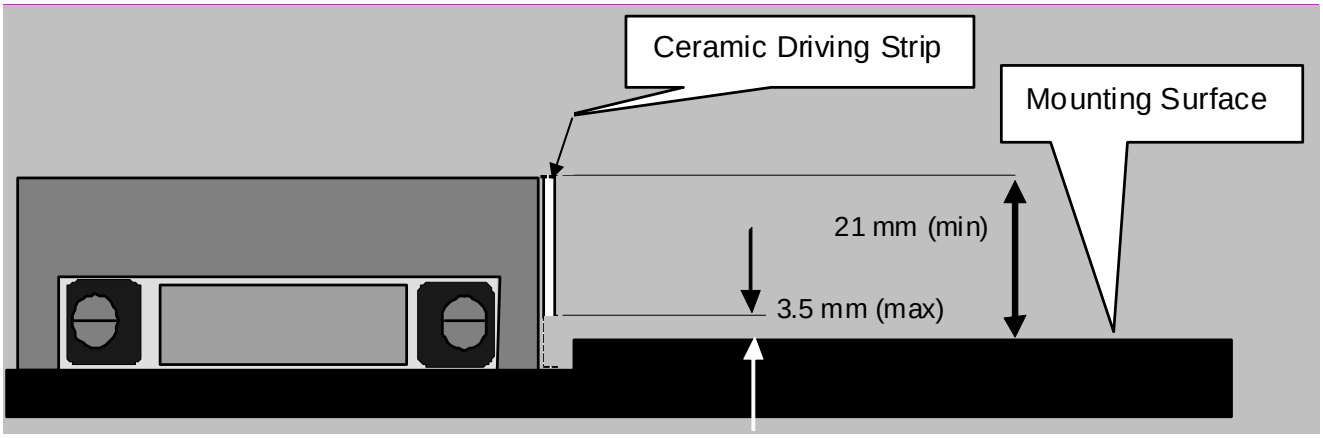

Figure 3: Ceramic Driving Strip Position

4. Referring to the figure below, apply two drops of epoxy adhesive, on the center of the Ceramic Driving Strip *upper* surface, about 2cm apart. The Epoxy must bond between the plate and the stage.

   Recommended adhesive:

   - Emerson & Cuming Ecobond 24, for vacuum applications
   - 3M 2216 epoxy or Arldite Radite, for non-vacuum applications

Notes:

- *Be sure the epoxy contacts the upper surfaces of the plate and the stage carriage but does not flow over the Ceramic Driving Strip front surface.*

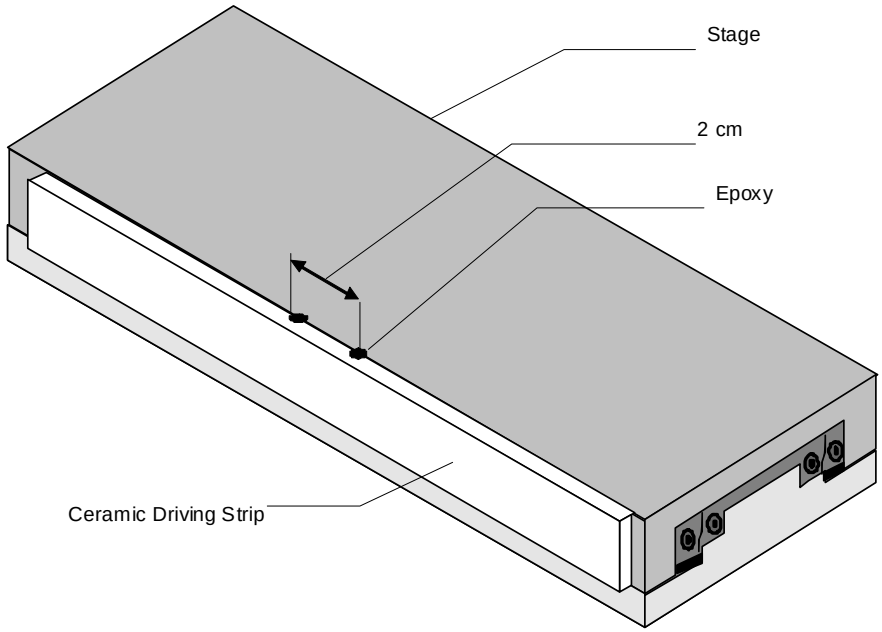

Figure 4: Securing the Ceramic Driving Strip to the Stage

5. Allow the required time period for curing, according to the Epoxy manufacturer specifications.
6. Mount the motor according to the following section.

3.2.2 Mounting the Motor

1. Retract the motor: using a 3mm flat screwdriver, turn both of the two preload setting screws counter-clockwise until the turn is completed and the slot is in the position illustrated below.

Notes:

- *The motor is usually supplied with the preload screws already retracted. If so, please continue to step 2.*

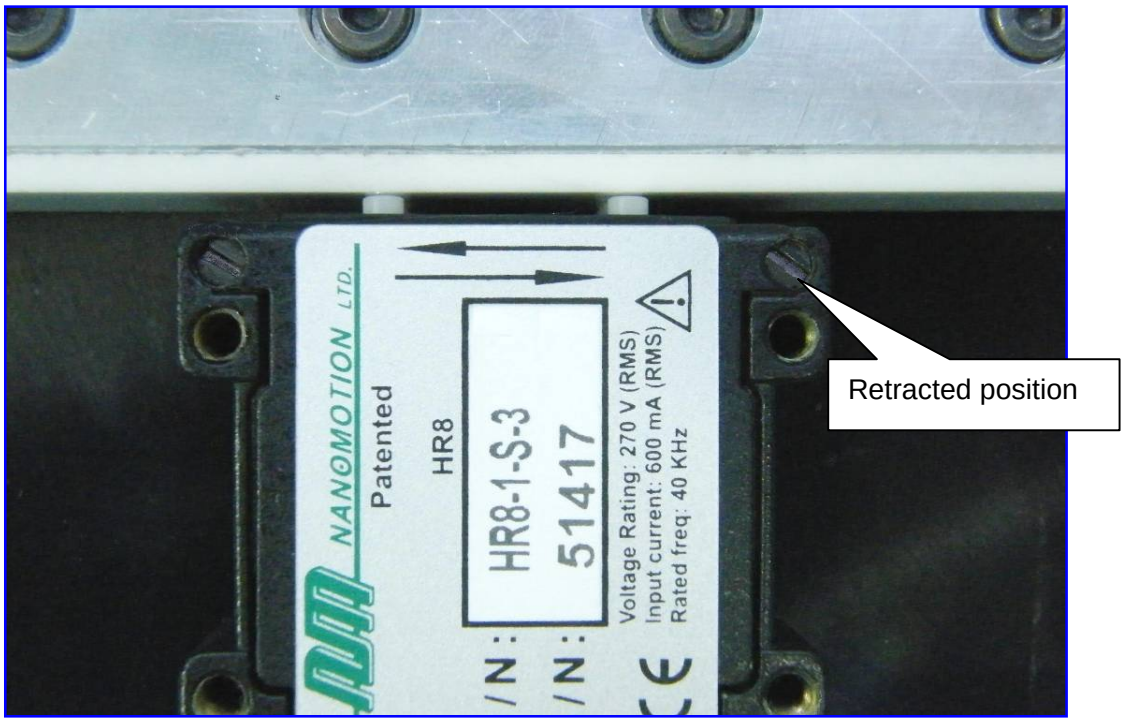

Figure 5: Preload Screws Retracted Position

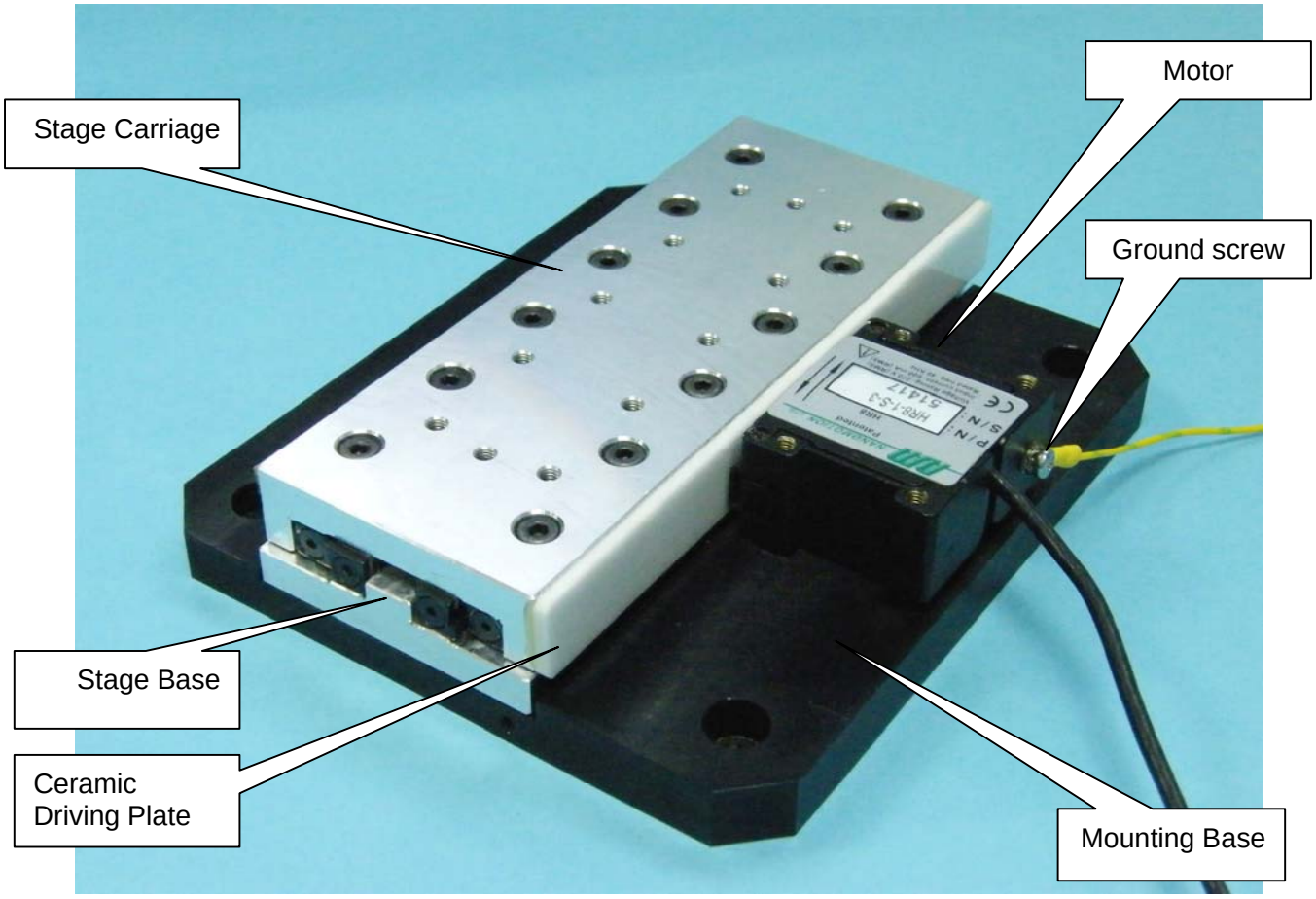

Figure 6: Mounting the Motor

2. While making sure not to exert any force on motor's 'finger tips', place the motor on the mounting base and loosely secure it using four M4 screws and spring washers inserted from the underside of the mounting base. **Do not tighten yet.**
3. *Gently* press the motor against the Ceramic Driving Strip, until it just contacts it and **tighten** the four screws of Step-2 at a torque of 0.5 - 0.7 Nm.

4. Release the preload setting screws: using again the 3mm flat screwdriver, turn both screws *clockwise* until the turn is completed and the slot is in the position illustrated below. The motor is now correctly mounted against the Ceramic Driving Strip.

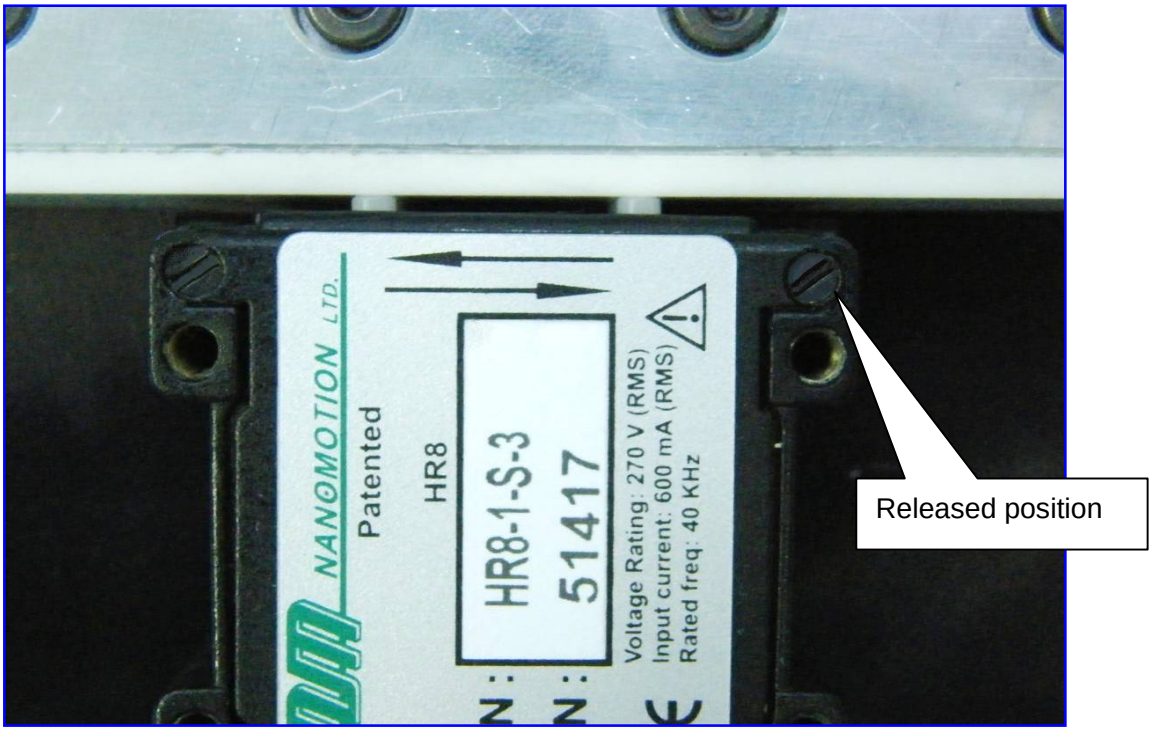

Figure 7: Released Position

5. Ground the motor according to the following section.

3.2.3 Motor Grounding

Warning!

Be sure to ground the motor to the electrical network ground (according to the following instructions) before operating the motor.

1. Prepare a grounding wire and terminal connection with the following specifications:
   - Terminal diameter - for an M3 screw
   - Wire diameter - minimum 18 AWG
   - Wire length - maximum of 2 meter
2. Open the motor ground screw (see Figure 6) and connect the Ground connection prepared in step-1.
3. Secure the terminal between the two lock washers.
4. Connect the other end of this cable to the electrical network ground.
5. Connect the motor to its driver according to the instructions given in the following section.

3.2.4 Motor Connections

This section describes the motor connector pinout and the connections to each of the available drivers. Make sure the driver is set to operate with the HR8 motor series.

CAUTION:

Reducing the length of the supplied motor cable *may damage* the motor. Do not attempt to shorten the cable without prior confirmation by Nanomotion.

Extending the motor cable will not damage the motor, however it will somewhat decrease its performance.

3.2.4.1 Motor Connector Pinout

⚠ **WARNING!**

Do not remove the cover of the motor or disassemble its connector. High voltage inside!

CAUTION:

Do not set power-on unless the motor is mounted and preloaded.

The motor driver connection is a standard 9 contacts D-type female connector whose pinout is given below.

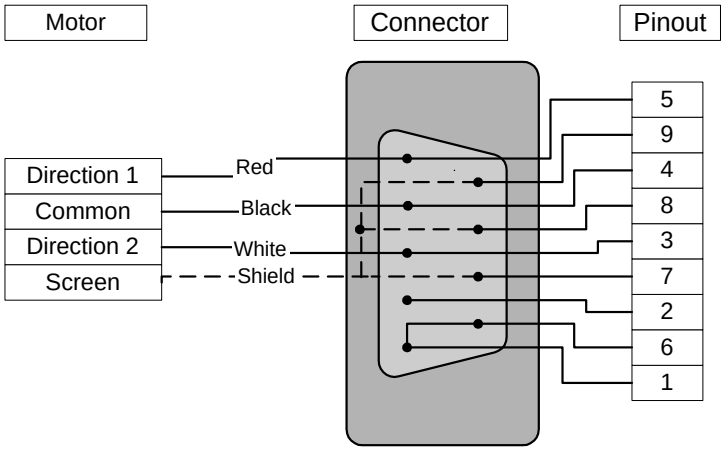

Figure 8: Motor Connector

Notes:

- *Pins 6 and 1 on the motor connector are shorted. This is done for safety reasons – driver voltage is disabled unless pins 1 & 6 are shorted when motor is connected.*

3.2.5 For Ultra High Vacuum motor:

The HR8 –1-U motor does not have an outlet cable or a connector. Instead, there are 3 TFE jacketed wires extending outside the motor: 1 black wire, 1 red and 1 white wire. The red and white wires are direction 1 and 2 respectively, and the black wire is the common. Also, the safety shorting between pins 1 and 6 is not implemented and should be performed by the user.

⚠WARNING!

Since there is no cable shielding the HR8-1-U motor case to ground, it must be grounded by means of connection to the network ground. Please refer to section 2.2.3 in the manual for detailed instructions

3.2.5.1 System Electrical Configuration

The Motor is to be operated by one of Nanomotion's drivers.

Following are the two possible configurations:

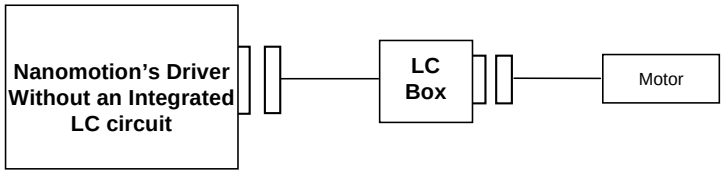

Figure 9: Connection to a Driver Using an External LC box

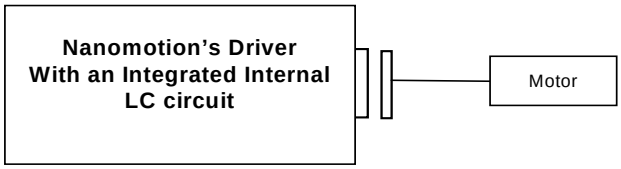

Figure 10: Connection to a Driver with Internal LC Circuit

3.2.6 Motor Run-In

Run-in of the motor is important to reduce wear rate of the system and to increase its lifetime.

The required run-in conditions are as follows:

- Velocity - 100 mm/sec.
- Acceleration - <1.5 m/s^2
- Duty cycle - 50%.
- Duration - 4 hours.

When the run–in is completed, carefully clean the Ceramic Driving Strip with a Q-Tip soaked with IPA, **without dismounting the motor**.

General remarks:

1. **The procedure should be repeated if the motor is disconnected and then reinstalled.**
2. **Do not perform run-in in a vacuum environment**.

4 Specifications

4.1 General

These specifications apply to the standard motor driven by the AB1A Driver Box. The motor features a linear voltage response. The motor and driver can be modeled as a DC-motor with friction driven by a voltage amplifier, as illustrated in the following diagram. .

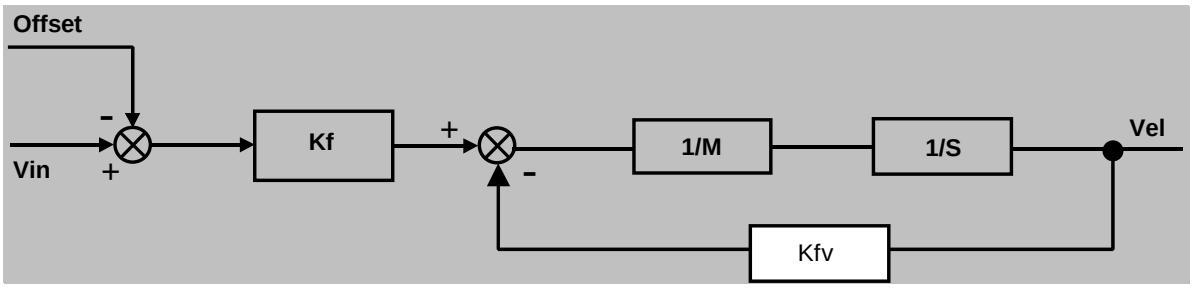

Figure 11: Block Diagram of the Motor and Driver

Where:

Vin	- Command to the driver -10 to +10 [V]
Kf	- Force constant [N/V]
Offset	- Starting voltage [V]
Kfv	- Velocity damping factor (phenomena similar to back EMF) [N x sec / m]
Vel	- Motor velocity [m/Sec]
M	- Moving mass [kg]
S	- Laplace variable [1/sec]

A block diagram of a typical HR8 Driver/Motor Sub-system is shown below.

A command voltage of ±10V is applied to the driver. The driver then generates a 39.6Khz sine wave (V motor) whose amplitude is a function of command voltage. The sine wave drives the HR8 motor.

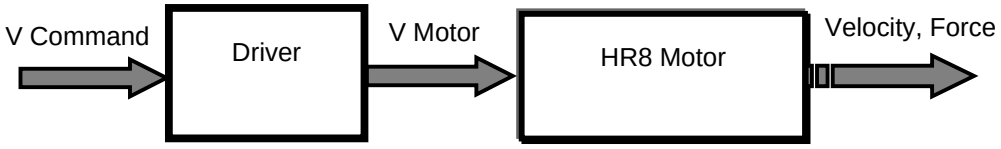

Figure 12: Block Diagram of a Typical HR8 Driver/Motor Sub-System

4.2 Specification Parameters

Performance	
Maximum Allowable Velocity:	250 [mm/sec]
Dynamic Stall Force:	30 to 36 [N]
Static Holding Force	28 [N] (reference value)
Non-Energized Stiffness	3.3 to 3.8 [N/μ]
Nominal Preload on Stage	144 [N]
Kf	4 [N/Volt] - driver & command dependant
Kfv	120 to 144 [N • sec/m]
Offset	1 to 2 [V] – driver dependant
Attainable Resolution	Better than 100nm – see application notes.
Nominal Lifetime	20,000 hours under nominal operating conditions
Electrical	
Maximal Voltage:	270Vrms, 39.6KHz, sine wave.
Maximal Current consumption:	600 mA rms
Maximal Power Consumption:	40W
Environmental	
Ambient Temperature:	0 - 50°C
Storage:	-40°C - +70°C
Humidity:	0 - 80% non condensing
Vacuum level (high-vacuum motors): Vacuum level (ultra-high-vacuum motors):	10^{-7} Torr (guaranteed only after baking) 10^{-10} Torr (guaranteed only after baking)
Maximum Baking Temperature (for vacuum motors):	110ºC (140ºC for ultra high vacuum motor)
Physical Dimensions	
Length:	41.9mm
Width:	46.6mm
Height:	23.8mm
Weight:	120/170 gr. (high & ultra high vacuum motors /standard motor)

4.3 Thermal Envelope of Performance (EOP)

4.3.1 Description

Motor operating temperature is a result of the balance between heat generation and heat dissipation.

- The heat generation depends on motor's work regime (driver command level).
- The heat is dissipated through the following heat transfer mechanisms: conduction, radiation and convection (the convection mechanism is negligible in vacuum environment).

The heat dissipation mechanisms should be able to dissipate the heat generated in order to avoid overheating. The EOP gives the user the tools to assess the permitted operating conditions (for set ambient temperature and command, deriving the duty cycle and maximal continuous operation that assures safe operation).

The user can either operate the motor for an extended period of time at a specific duty cycle or alternatively, can operate the motor for a continuous time period specified under “Maximal Continuous Operation Time” (see graphs and tables in sections 4.3.3 and 4.3.4). After the continuous operation is completed, the driver must be disabled to cool down the motor for 400 sec in air and for 700 sec in vacuum environment.

Notes:

- *The duty cycle is the ratio of the operation time and the total work cycle (operation time + idle time).*
- *When operating the motor with the AB5/AB51 driver continuously in Brake_Off Mode (refer to section 4.3.4 "EOP for HR Motors Driven by AB5, AB51 Driver"), the motor consumes power at all times, even when the control command voltage is "0" (zero) thus the time at "0" command is accounted in the heating process and reduces the thermal EOP.*
- *Upon operating a motion system in vacuum, it is expected that the Coefficient of Friction of the bearing structure will increase. This may require changing the system operation point on the thermal EOP curves.*

4.3.2 Stage Heat Dissipation Consideration

The motor heat dissipation mechanism is by convection and radiation to the motor case, and by conduction through motor's 'finger tips'. Hence, the motor and the Ceramic Driving Strip bases, must both be thermally designed to dissipate 2W each (per motor's 'finger tip'), with maximum temperature rise of 15°C.

4.3.3 Thermal EOP for HR8 Motor Driven by AB1A, AB2 AB4 Drivers

Figure 13 illustrates motor velocity as a function of the applied driver command voltage. Allowing up to 30 mm/sec variations, use it as a reference and as a guideline for expected motor performance:

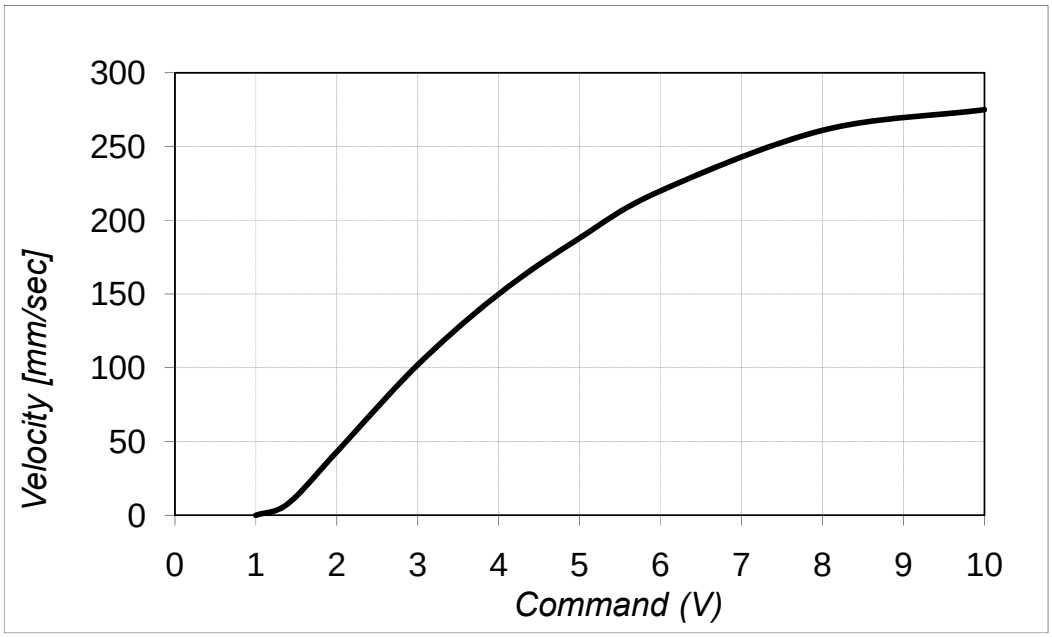

Figure 13: Motor Velocity vs. Command[1]

[1] The motor operates horizontally at room temperature and low duty cycle (< 10%). It interfaces with the Ceramic Driving Strip (according to Nanomotion Specifications) and a cross-roller high quality slide.

Figure 14 and Table 1 are designed to help the user determining the correct envelope of performance and avoid overheating and damaging the motor.

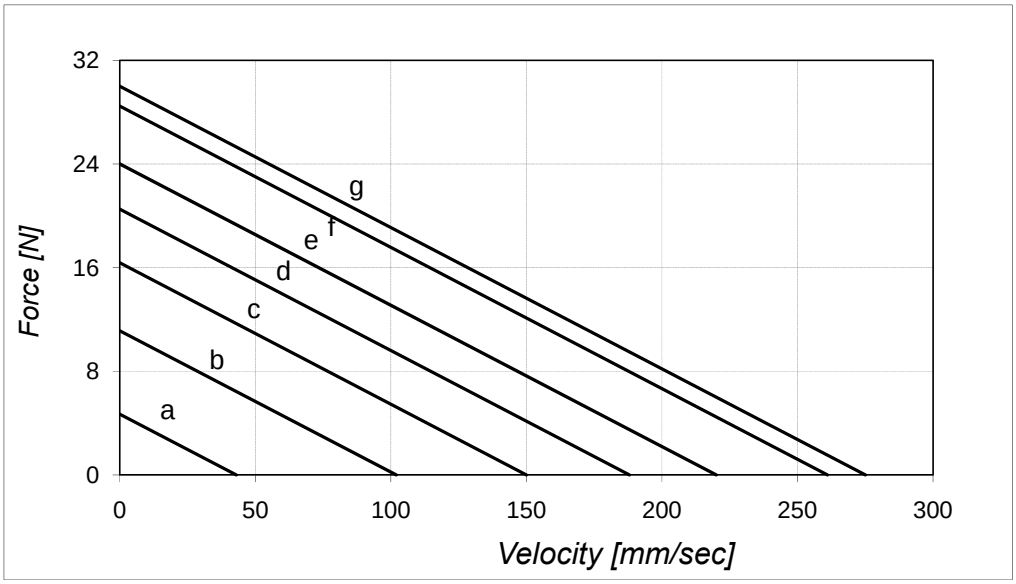

Figure 14: Motor Force vs. Velocity at the Various Work Regimes (a-g)

AB1A, AB2, AB4						
Curve	Air 25°C		Air 50°C		Vacuum	
	Duty Cycle [%]	Maximal Continuous Operation time [sec]	Duty Cycle [%]	Maximal Continuous Operation time [sec]	Duty Cycle [%]	Maximal Continuous Operation time [sec]
a	100	∞	100	∞	100	∞
b	100	∞	100	∞	44	184
c	100	∞	92	137	26	107
d	100	∞	62	93	17	72
e	78	87	47	70	13	55
f	56	62	33	50	9	39
g	50	56	30	45	8	35

Table 1: EOP Table for HR Motors Driven by AB1A, AB2, AB4

4.3.3.1 An Example for Defining the EOP for AB1A Driver in Vacuum Environment

An example for using the graph and table (Figure 14 and Table 1) for the AB1A driver:

A vacuum application requires 10N at a velocity of 100mm/sec. The graph shows that this point of operation corresponds to the curve “d”.

The table shows that curve “d” and a vacuum environment require that a duty cycle of 17% will not be exceeded and the maximum continuous operation time is limited to 72 seconds.

4.3.4 EOP for HR Motors Driven by AB5, AB51 Drivers

The AB5, AB51 drivers are preferable for a perfect servo tracking and/or very low ripple constant velocity. Refer to the "AB5 and AB51 Drivers User Manual", D/N: AB05458200. The AB5 unique features result in the motor consuming more power and in a lower EOP, compared to the EOP for a motor operating with the AB1A driver.
The AB51 driver is a modified version of the AB5 driver, which gives a higher EOP, compared to the AB5 driver, with some adverse effect on control performance in respect to tracking error and low velocity ripple.

Figure 15 illustrates motor velocity as a function of the applied AB5/AB51 driver command voltage. Allowing up to 30 mm/sec variations, use it as a reference and as a guideline for expected motor performance:

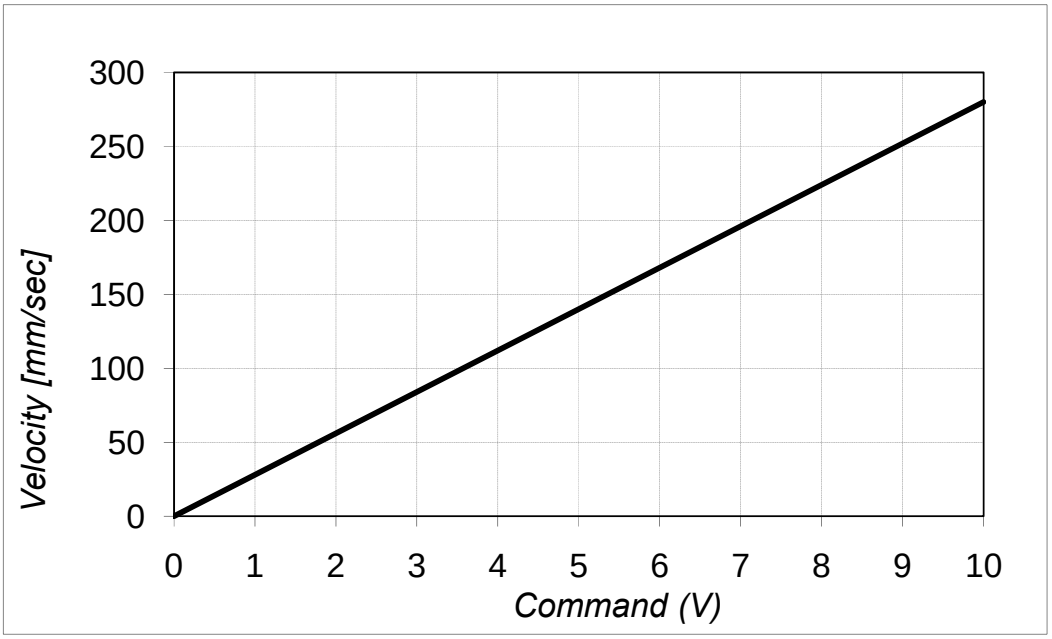

Figure 15: Velocity vs. Command Using the AB5/AB51 Driver

Figure 16 and Table 2 are designed to help the user determining the correct envelope of performance and avoid overheating and damaging the motor.

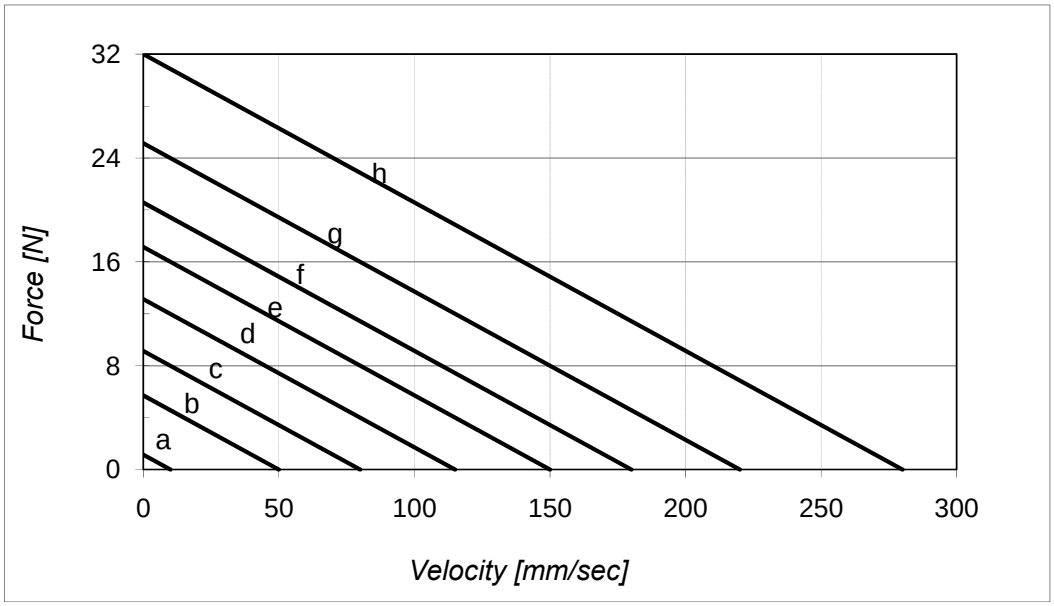

Figure 16: Force vs. Velocity Using the AB5/AB51 Driver at the Various Work Regimes (a-h)

AB5					
Curve	**Air 25°C**			**Vacuum**	
	Duty Cycle Brake_ Off [%]	**Duty Cycle Brake_On [%]**	**Continues Operation [sec]**	**Duty Cycle Brake_On [%]**	**Continues Operation [sec]**
"0"÷a	100	100	∞	28	230
b	100	100	∞	23	210
c	100	100	∞	19	150
d	100	100	∞	14	110
e	50	80	280	13	90
f	33	58	170	12	66
g	24	45	77	10	44
h	11	28	32	6.5	25

Table 2: EOP Table for HR Motors Driven by AB5 (Standard LUT)

AB51					
Curve	Air 25°C			Vacuum	
	Duty Cycle Brake_ Off [%]	Duty Cycle Brake_On [%]	Continues Operation [sec]	Duty Cycle Brake_On [%]	Continues Operation [sec]
"0"÷a	100	100	∞	56	500
b	100	100	∞	54	450
c	100	100	∞	45	280
d	100	100	∞	33	170
e	100	100	∞	23	100
f	53	58	170	12	66
g	33	48	77	10	44
h	17	28	32	6.5	25

Table 3: EOP Table for HR Motors Driven by the AB51 Driver (Reduced LUT).

Note:

- *In the Brake_Off Mode the full advantage of the AB5 driver is enabled giving a linear response, best tracking and low velocity performance. Using this mode, the motor operates continuously, even at "0" command and special attention must be given to maintain the work regime within the permitted "Duty Cycle" and "Maximal Continuous Operation Time" (refer to Table 2 and Table 3). Once the operation time has reached the "Maximal Continuous Operation Time", even at Brake_Off Mode without motion (!) the driver must be disabled to allow the motor to cool down for at least 400 seconds in air and 700 sec in vacuum environment.*

4.3.4.1 An Example for Defining the EOP for AB5 Driver in Vacuum Environment, Brake_On Mode

A vacuum application requires 8N at a velocity of 80mm/sec and the motor is disabled when stand still (Brake_On Mode). The graph (see Figure 16) shows that this point of operation corresponds to the curve “e” (see Table 2).

Table 2 for AB5 in Brake_On Mode shows that curve “e” and a vacuum environment require that a duty cycle of 13% will not be exceeded and the maximum continuous operation time is limited to 90 seconds. Alternatively AB51 can be used giving duty cycle and continuous operation of 23% and 100 sec respectively.

The same conditions under Air at 25°C will result in 100% Duty Cycle and unlimited continuous operation.

4.3.4.2 An Example for Defining the EOP for AB5 Driver in Vacuum Environment, Brake_Off Mode

When Brake_Off Mode is used under vacuum conditions the motor will overheat at any duty cycle, if operated for a prolong time. To calculate the max operation time, use curve "0÷a" (see Table 2) for time at “0” command and the operation curve for the operating time according to the following formula:

T_{max}=(max continues operation at the operation regime) * DC + (max continuous operation under regime "a")*(1-DC).

If operating under curve "c" (see Table 2), using AB5 in a duty cycle of 10%, the total operation time is:
Tmax=150 *0.1 +230*(1-0.9)=222 sec

Once Tmax is reached, the driver should be disabled for a period of 700 sec.

4.4 Schematics

4.4.1 Dimensions for Standard and High-Vacuum Motors

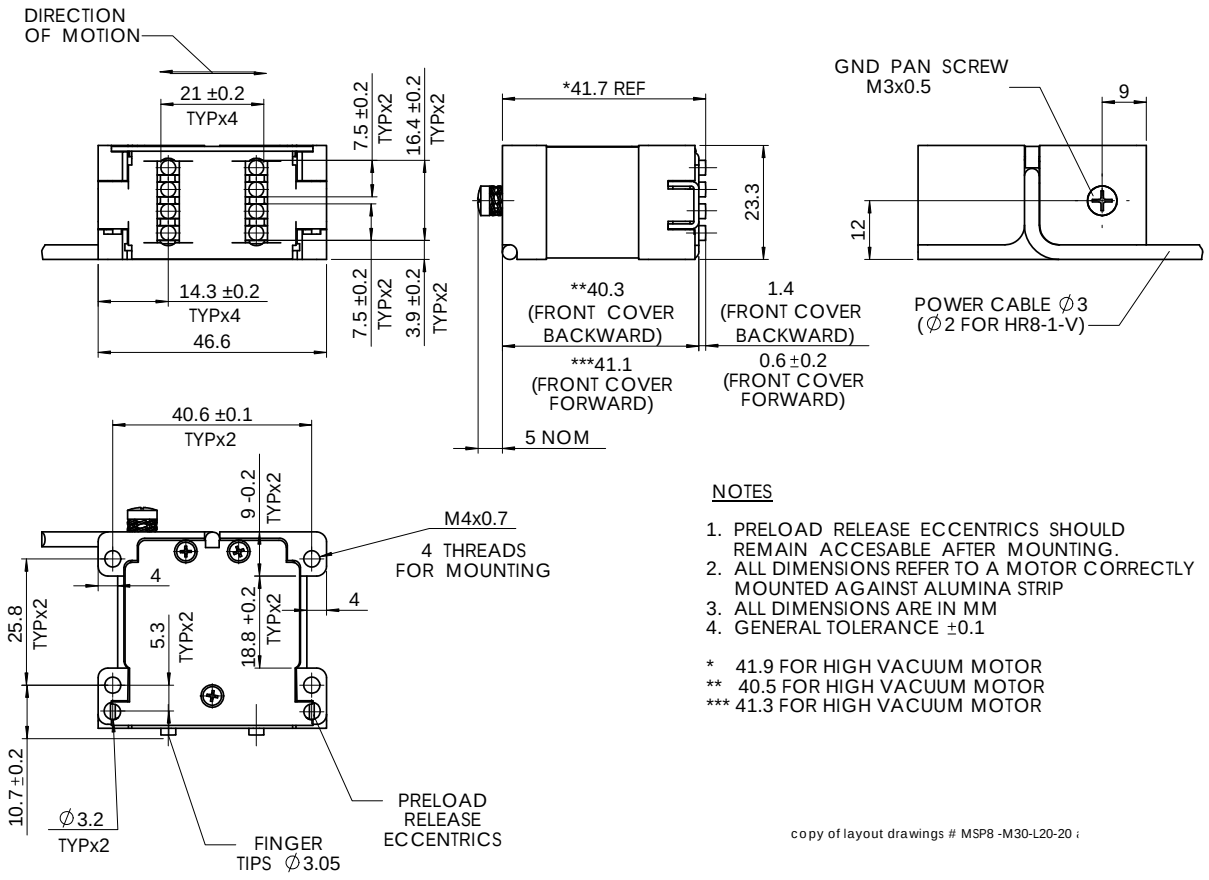

Figure 17: Dimensions for Standard and High-Vacuum Motors

4.4.2 Dimensions for Ultra-High-Vacuum Motors

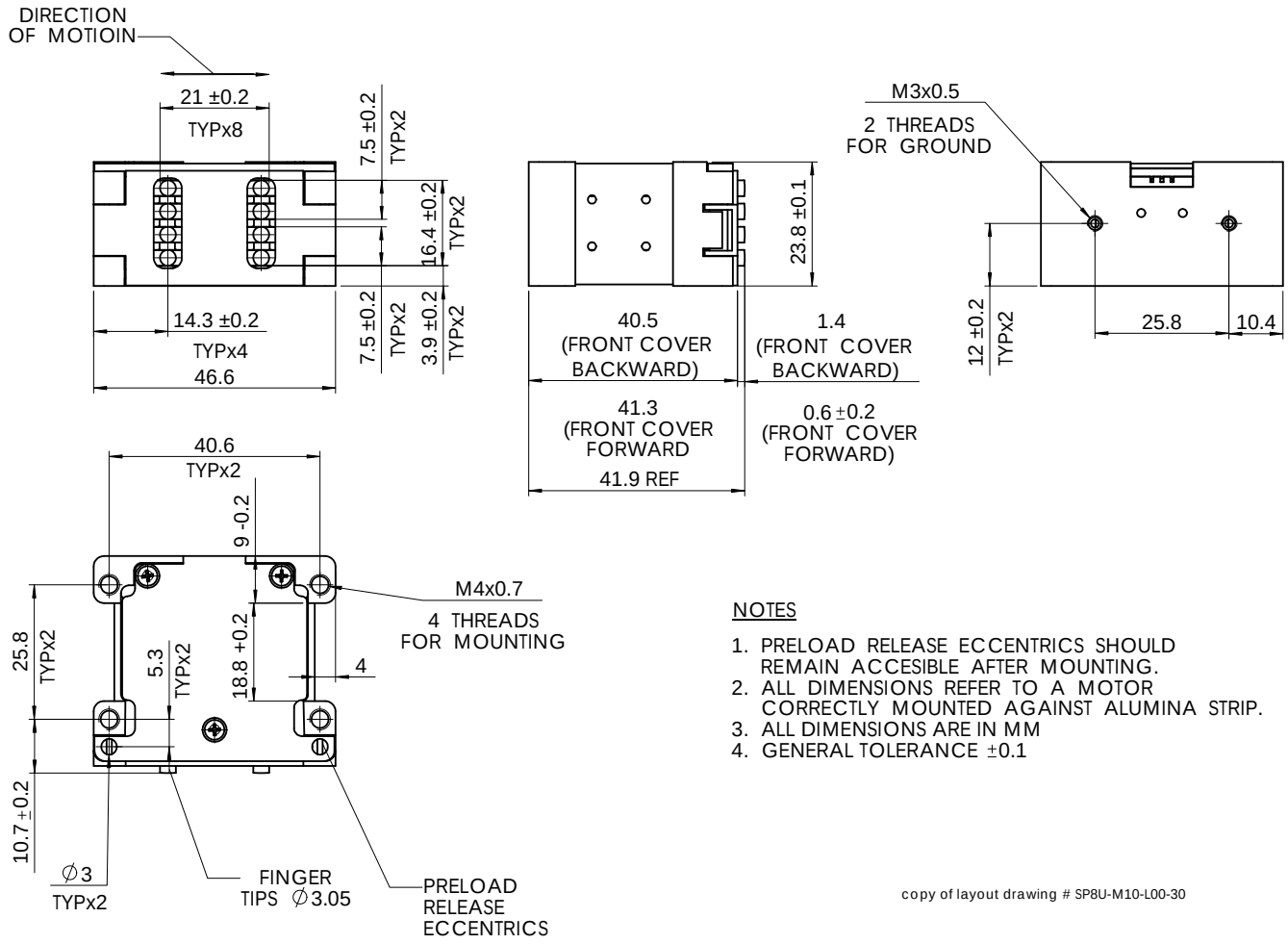

Figure 18: Dimensions for Ultra-High-Vacuum Motor

4.4.3 Mounting Base Dimensions

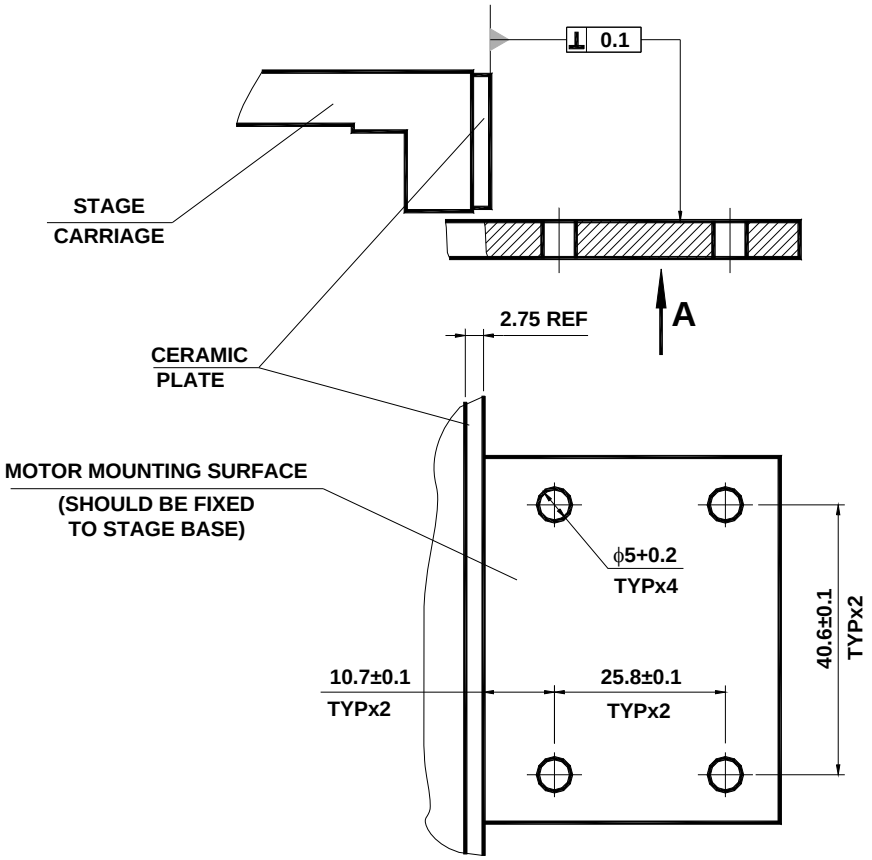

Figure 19: Base Layout

5 Contact Information

5.1 Customer Service

Contact your local distributor or email Nanomotion Ltd. Technical Support Department at techsupport@nanomotion.com, with detailed problem description, additions, corrections or suggestions.

5.2 General Inquiries and Ordering

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